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MICRO-EMULSION FUEL ADDITIVE

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BACKGROUND OF THE INVENTION

1. Field of Invention

This invention relates to a micro emulsion forming fuel additive containing water which improves combustion of liquid hydrocarbon fuels.

2. Cross References to Related Patents

This application is a continuation-in-part patent application of Serial No. 09/588,029, filed 5 June 2000; which is a continuation-in-part of 09/039,675, filed 16 March 1998, now abandoned; which is a continuation-in-part of 08/629,802, filed 10 April 1996, now abandoned; which is a continuation-in-part of 08/296,457, filed 26 August 1994, now abandoned; which is a continuation-in-part of the parent application 08/153,049, filed 17 November 1993, now abandoned.

3. Relevant Prior Art

It is generally known that water improves combustion of hydrocarbon fuels. There is disagreement as to the mechanism by which the improvement is achieved. Theories include micro-explosions and another theory speaks of an extra hydroxyl radicals. In any event, water in 20,000 parts per million ("ppm") is generally believed necessary to achieve a worthwhile improvement as taught in U.S. Patent 4,315,755. Amounts of water as little 1,000 ppm are taught as achieving some improvement as taught in U.S. Patent 4,396,400.

Water and hydrocarbon fuels do not stay mixed and several strategies have been employed to achieve mixing for combustion purposes. U.S. Patent 1,701,621 teaches significant mechanical agitation of water droplets of greater than 0.4 microns using a small quantity of emulsifying agent. U.S. Patent 3,876,391 teaches water droplets of less than 0.4 microns with more emulsifying agent and little mechanical agitation.

Fuel/water macro-emulsions have been used for many years in boilers where heavy fuel oil is burned to raise steam. U.S. Patent 4,244,702 discloses that these macro-emulsions are very effective in reducing smoke and NO_x emissions while keeping the heat transfer surfaces clean of significant combustion deposits.

Grangette et al U.S.Patent 4,396,400 discloses that it is possible to produce a low water content emulsion by adding at least 100 ppm of additional water in forming a micro-emulsion fuel with a low surfactant content 25 ppm, which gives reasonable emissions reductions when tested in a vehicle on a chassis dynamometer. However, such a mixture is not stable at a surfactant to water ratio of 0.25:1 and has not been adopted in the real world.

SUMMARY OF THE INVENTION

OBJECTS OF THE INVENTION

It is an object of this invention to provide additional water to liquid hydrocarbon fuels in the form of a micro-emulsion to enhance fuel efficiency.

A further object is to reduce toxic exhaust emissions.

Yet another object is more complete combustion.

DESCRIPTION OF PREFERRED EMBODIMENT

Fuel additive compositions are formulated which can be mixed with commercially available liquid hydrocarbon fuels (such as gasoline, diesel fuel or jet fuel) to form stable "water-in-oil" type micro-emulsions. Improved combustion and efficiency can be achieve by adding as little of the composition as needed as to result in 5 to 95 ppm (parts per million) of additional water in the hydrocarbon fuel. Stability of this low water content micro-emulsion fuel is achieved with use of high surfactant to water ratios in the additive between 8.0:1 and 0.5:1, preferably between 3.0:1 and 1.0:1 and most preferably 2.5:1. The resulting micro-emulsion fuel exhibits improved fuel economy and reduced exhaust emissions.

The fuel additive composition should be added to commercially available liquid hydrocarbon fuels at a dose ratio such that the additional water in such fuel comprises from 5 to 95 ppm by weight of the hydrocarbon fuel. The additive before adding should comprise from 10% to 65% by weight of water, preferably 25% to 50% by weight of water; from 0% to 25% by weight of one or more co-surfactants selected from the group consisting of alcohols, glycols, and ethers preferably selected from the group consisting of C_1 to C_4 alcohols, ethylene glycol and

glycol ethers; and the balance up to 100% by weight of one or more surfactants selected from the group consisting of amphoteric, anionic, cationic and non-ionic surfactants, preferably selected from the group consisting of amine alkylbenzene sulphonate, POE (20) sorbitan monooleate, tall oil fatty acids, oleyl imidazoline hydrochloride and oleamide diethanolamine; and such that the ratio of the surfactant to the water falls within the range from 0.5:1 up to 8.0:1, preferably within the range 1.0:1 to 3.0:1 and most preferably 2.5.1.

The fuel additive compositions including the preferred ones are prepared by mixing the above components sufficiently to produce a micro emulsion forming additive.

A suitable liquid fuel composition is prepared by mixing a liquid hydrocarbon fuel with the above described micro-emulsion forming additive so that the composition comprises:from 10 to 400 ppm of one or more surfactants selected from the group consisting of amphoteric, anionic, cationic and non-ionic types; from 0 to 100 ppm of one or more co-surfactants selected from the group consisting of alcohols, glycols, and ethers; and from 5 to 95 ppm of added water with the ratio of surfactant to added water being in the range from 0.5:1 to 8.0:1; and the remaining portion is liquid hydrocarbon fuel. A preferred range for the added water is in the range of 20 to 80 ppm. A preferred ratio of surfactant to added water being in the range of 1.0:1 to 3.0:1. A preference in surfactants is a selection from the group consisting of amine alkylbenzene sulphonate, POE (20) sorbitan monooleate, tall oil fatty acids, oleyl imidazoline hydrochloride and oleamide diethanolamine. A preference in the selection of the co-surfactants is selected from the group consisting of C_1 to C_4 alcohols, ethylene glycol and glycol ethers. A preference in the liquid hydrocarbon fuel is from the group boiling in the gasoline to diesel fuel range;

Internal combustion engines normally show variations in the maximum cylinder pressure and rate of pressure rise from cycle to cycle which is known as cyclic dispersion. This is due to variations in turbulence between cycles which vary flame speeds across the combustion chamber.

The inventive micro-emulsion when existing within the body of the fuel tends to reduce these cyclic dispersions. This is turn results in a smoother running engine with lower emissions, improved fuel economy and reduced engine octane requirements.

The on-set of combustion in both gasoline and diesel engines is governed by chaos theory. In other words, the way combustion progresses from that point on is extremely sensitive to the initial conditions. If conditions vary even slightly from cycle to cycle, then the subsequent growth of the combustion flame will also vary, but to a much greater extent. This extreme sensitivity to initial conditions is the primary cause of cyclic dispersions.

Thus even an extremely small but beneficial effect at the on-set of combustion has a disproportionally large effect upon the manner in which the combustion subsequently progresses. This mechanism has not been appreciated and utilized by others in the past.

As a gasoline engine accumulates engine hours, its fuel octane requirement increases, sharply at first, and then more gradually until it stabilizes. This process takes 400 engine hours on average. This octane requirement increase (ORI) is caused by the gradual build up of carbon deposits in the engine combustion chambers. Initially, the preferred octane requirement for a brand new engine might be as low as 78 to 80 octane (R+M/2). After 400 engine hours this preferred requirement has increased to 87 to 89 octane (R+M/2).

The addition of our low water content micro-emulsion to fuels does not significantly increase the octane rating of the fuel but does significantly reduce the octane requirement of the engine. Fuel cost traditionally increases with the octane rating of the fuel so that a lower octane requirement translate in to a financial savings.

The lower octane benefit is achieved in two ways. The reduction in cyclic dispersions reduces the octane requirement. Secondly, a more gradual improvement appears with a dirty engines. Use of the additive results in "micro-explosion" which have a cleaning action which

slowly removes the accumulated combustion chamber deposits and in turn slowly reduces the octane requirement.

The factors which govern fuel micro-emulsion droplet size and stability at low treat rates are several. Two of the most significant of these factors are the background level of dissolved water already present in the fuel, and the continuous dynamic balance between fuel and water in a typical fuel tank.

A typical fuel tanks comprises a vented tank, partially filled with fuel containing some dissolved water, an air space containing some water vapor above the fuel and within the tank, and a small quantity of free water at the bottom of the tank. There exists a continuous interchange of water between these three distinct zones. This interchange is driven in part by ambient temperature fluctuations outside the tank. There are typical day/night temperature cycles, heating caused by fuel re-circulation which occurs in fuel injected vehicles, radiation from hot exhaust pipes and possible exposure of tank surfaces to direct sunlight.

Automotive hydrocarbon fuels typically contain some dissolved water as normal contamination. The maximum quantity of dissolved water varies with the type of fuel and its temperature. Fluids have a solubility constant for water and will vary by class of fuels such as gasoline, diesel, kerosene and not greatly within the class. At normal ambient temperatures (20 deg. C), a typical automotive gasoline (no oxygenates), or diesel fuel, will contain 50 to100 ppm of dissolved water.

The prior art teaches adding 10,000 ppm of emulsified water together with 5,000 ppm of surfactant which renders the background level of 100 ppm of dissolved water of no significance. However, for the present invention, this background level has significance and is not overwhelmed by addition of for example 30 ppm of emulsified water together with 75 ppm of surfactant. Knowledge of the solubility constant for the class of fuel to be treated is an important

essential so that the level of background water is considered and factored into the addition. The ratio of surfactant to water is increased as necessary so that subsequent to mixing with the fuel, the ratio of surfactant to water in the additive are of within preferred ratios.

It is this background level of water, and the continuing cycle of temperature changes, that sets the practical lower limit for the concentrated micro-emulsion dose rate. The additive dose must contain enough water to quickly create an effective initial micro-emulsion, together with sufficient additional surfactants to accommodate the potential quantities of extra water already dissolved in the fuel, as well as water contamination from the fuel environment.

Unavoidable variations in fuel quality, together with differences in fuel specifications (reformulated gasoline), means that emulsion droplet sizes can vary considerably, as well as water volume and hence surface area. For this reason, any kind of laboratory static engine test gives only a general indication of "real world" results. Testing under lab conditions is not a very reliable indicator of long term micro-emulsion performance.

Survival and consistent performance for a low treat rate fuel emulsion in the "real world" environment are several orders of magnitude more difficult than in a lab. Also, migration by some of the oil soluble surfactants away from the emulsion droplets and into the main body of the fuel tends to slowly degrade the fuel emulsion.

Because only a small quantity of about 30 ppm water is being added, a micro-emulsion forming concentrate can be used as an additive for use in already existing and commercially available liquid hydrocarbon fuels. This results in the following advantages. Even with a high ratio of surfactant to water is employed, the low water requirement overall results in a low cost treatment relative to the fuel savings. With less surfactant being used per gallon of fuel, relative to other treatments, there less emissions from incomplete combustion of surfactants. Even if over time the micro-emulsion breaks down, the amount of released water is not large and can be

absorbed by the fuel. The expected improvement may be lost but no damage to the engine will occur which could lead to possible product liability claims. The smaller volumes involved with these additives are more readily acceptable to oil refineries and fuel distribution centers because the hardware already exists to incorporate other types of additives on this scale into the base fuels. If the whole fuel had to be emulsified and mixed after the refining process, the complexity and effort would dictate against employment.

The additives of the invention are a concentrate that can be conveniently packaged and sold over the counter in retail outlets. Extra surfactants are used to form the additive (increasing the ratio of surfactant to water) and although this raises the additive treatment cost it also greatly improves the stability of the final fuel emulsion (grades of gasoline and diesel fuel can vary considerably from batch to batch). It also allows for the ability to accommodate existing traces of dissolved water, which are usually present as contamination in most commercial fuels. The water phase of the additive can be used to carry water soluble combustion catalysts well known to those skilled in the art. These water soluble compounds usually being significantly less expensive and more readily available than the fuel soluble types currently being employed.

Generally liquid fuels do not burn until vaporized. In addition complete combustion requires intimate mixing of fuel vapor and air in the correct proportions. Micro-explosions help to vaporize the fuel as well as promote more efficient air/fuel mixing.

Because of the background level of dissolved water already present in the fuel or expected to be absorbed, it is essential that a sufficiently high surfactant to water ratio be used when producing the concentrated micro-emulsion forming additives of the invention. This ratio should be in the range from 8:1 to 0.5:1and preferably 3:1 to 1:1. This is necessary to give the resulting emulsion fuel sufficient extra surfactant(s) to remain stable during the anticipated emulsion fuel lifetime when extra water will be absorbed from the fuel.

Combustion of liquid hydrocarbon fuels is improved by preparing a concentrated micro-emulsion forming additive by mixing of a surfactant, a co-surfactant, and water. The following ratios (basis water = 1.0) have been found to be effective:

Liquid	Preferred Ratio	Ratio Range
Surfactant(s)	3.0 to 1.0	8.0 to 0.5
Co-surfactant(s)	1.0 to 0.5	2.0 to 0.0
Water	1.0	1.0

A sufficient amount of the micro-emulsion additive is mixed with the fuel to form a multitude of dispersed micro-emulsified water droplets, each droplet having an initial diameter within the range from 0.3 microns to 0.003 microns. These dispersed micro-emulsified water droplets remain in stable suspension within the liquid hydrocarbon fuel until such time as combustion of the fuel occurs.

Pre-diluting the concentrated additive with kerosene (or some other solvent/distillate) at the ratio from 50:1 to 1:50 can be used to improve mixing. Without adequate mixing, performance improvements may take as long as 24 hours for the concentrate to properly form into an effective emulsion after simply pouring the additive into the hydrocarbon fuel.

The ratio of liquid hydrocarbon fuel to concentrated micro-emulsion forming additive should fall within the range from 240:1 to 12,000:1. The treat rates are chosen so as to result in a micro-emulsified water content added to the hydrocarbon fuel in the range from 5-95 ppm, and typically 20-80 ppm.

The following ppms added to the hydrocarbon fuel have been found to be effective:

Liquid	Typical ppm	ppm Range

Surfactant(s)	50 to 150	10 to 400
Co-surfactant(s)	20 to 40	0 to 100
Water	20 to 80	5 to 95

Since most hydrocarbon fuels already contain some trace quantities of dissolved water as contamination (typically up to 100 ppm, considerably more for some oxygenated gasolines), it is quite possible to prepare a concentrated additive without using any water at all (although this type of additive would need extra time to become fully active in a typical fuel tank environment).

Although this invention has been illustrated by reference to specific embodiments, it will be apparent to those skilled in the art that various changes and modifications may be made which clearly fall within the scope of this invention.

Unless otherwise stated, all ratios, percentages and parts used herein are by weight.

EXAMPLES

Please note that in all of the following examples we have deliberately used various combinations of already existing and commercially available surfactants and co-surfactants to produce our micro-emulsion forming concentrates for use as low treat rate fuel additives. This has been done to show that the additives of the present invention are not limited to any specific combination of particular surfactant(s) or co-surfactant(s). Each additive example has the high surfactant to water ratio (up to 8:1) necessary for long term fuel emulsion stability.

There must be many other such additives possible (using different combinations of other surfactants and co-surfactants) that could also be used to produce micro-emulsion forming fuel additives. We refer specifically to Hazbun et al (U.S.#4,744,796) which clearly demonstrates that many different micro-emulsion fuels can be produced using diversely different types of surfactant and co-surfactant combinations.

These other combinations might be better (or worse) than the specific examples which follow. Some may have better high (or low) temperature stability, or have improved pour point, flash point, cost, viscosity, corrosiveness, commercial availability, toxicity, freezing point, color, smell, legislative acceptability, or any number of other particular benefits depending on the balance of importance prevailing at the time.

The heart of our technique is to produce a low water content liquid hydrocarbon micro-emulsion fuel by using a concentrated micro-emulsion forming additive having a sufficiently high (up to 8:1) surfactant to water ratio sufficient to give long term fuel emulsion stability.

Similar additives might also be produced by using some other combination of surfactants and co-surfactants. In other words, it does not really matter which surfactant and co-surfactant combinations are used, provided that they are adequate. Some combinations will probably be better than others in some way or other, but it is the use of a low treat rate micro-emulsion forming additive (having a high surfactant to water ratio) which is crucial to the practical application of our technique.

To confirm the validity of our claim to be unique by using a low treat rate micro-emulsion forming fuel additive (having a high surfactant to water ratio), each of the following examples (#1 through #12) illustrating our technique uses a different surfactant and co-surfactant combination to produce a concentrated micro-emulsion forming additive. These additives were then used to produce low (less than 100 ppm) water content micro-emulsion fuels.

These micro-emulsion fuels were then tested to look for benefits similar to those claimed in the "high water content" emulsion fuel Prior Art (typically, reduced emissions and improved octane etc.).

Co-Surfactants Used for Various Examples:

Although certain chemicals have been mentioned specifically by name as suitable co-surfactants, various other alcohols, glycols, ethers and amines might also be suitable, even some of the amides, diols and aldehydes might prove effective.

TABLE 1 (Surfactants Used for Examples #1 Through #12):

Trade Name	Chemical Name	Type	Supplier
Arquad T-50	Trimethyl Tallow Alkyl Quat	Cationic	Akzo Nobel
Aristonate "M"	Sodium Alkyl Aryl Sulfonate	Anionic	Pilot
Aristonate "L"	Sodium Alkyl Aryl Sulfonate	Anionic	Pilot
Cembetaine CAS	Cocoamidopropyl Hydroxysultaine	Amphoteric	Chemron
Hamposyl C-30	Sodium Cocyl Sarcosinate	Anionic	Hampshire
Makon 4	Ethoxylated Alkylphenol	Non-ionic	Stepan
Makon 8	Ethoxylated Alkylphenol	Non-ionic	Stepan
Norfox TLS	Triethanolamine Lauryl Sulfate	Anionic	Norman Fox
Ninate 411	Amine Alkylbenzene Sulfonate	Anionic	Stepan
Span 80	Sorbitan Monooleate	Non-ionic	ICI
Surfonic L24-4	Linear Alcohol Ethoxylate	Non-ionic	Huntsman
Surfonic L24-9	Linear Alcohol Ethoxylate	Non-ioni	Huntsman

Examples #1 through # 12 which follow illustrate the present invention in various forms. We employed seven completely different test vehicles. Three were gasoline powered and four were diesel powered. Two were from USA, three from Europe, and two from Japan. Ages and mileages were also widely different.

When mixing the water, surfactant(s) and cosurfactant(s) to produce the additives used in these examples, the following technique was used:

For those additives containing kerosene, this was the first ingredient.

For those additives without kerosene, the co-surfactant(s) was the first ingredient. Next the surfactant(s) were added using gentle stirring.

Finally, the water was added slowly and stirred until the resulting additive was clear and stable. Regular city water was used in all examples.

TABLE 2 (Percentage Composition For Examples #1 through #12):

	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12
Kerosene	-	-	-	-	-	-	20	30	-	20	20	-
Arquat T-50	-	-	-	-	-	-	-	-	-	-	-	20
Aristonate "M"	-	35	-	-	-	-	-	-	-	-	-	-
Aristonate "L"	-	25	-	-	-	-	-	-	-	-	-	-
Cembetaine CAS	-	-	-	-	-	-	-	-	-	-	10	-
Hamposyl C-30	-	-	-	-	4	-	-	-	-	-	-	-
Makon 4	-	-	-	-	-	20	-	20	-	30	-	-
Makon 8	-	-	-	25	-	10	-	10	-	30	-	-
Norfox TLS	-	-	-	-	-	-	7	-	-	-	-	-
Ninate 411	70	-	-	-	-	30	-	30	30	-	60	-
Span 80	-	-	-	55	66	-	53	-	50	-	-	50
Surfonic L24-4	-	-	40	-	-	-	-	-	-	-	-	-
Surfonic L24-9	-	-	40	-	-	-	-	-	-	-	-	-
Methanol	-	-	10	-	-	-	-	-	5	-	-	-
Ethanol	-	-	-	10	10	-	-	-	-	-	-	-
Iso Propanol	20	-	-	-	-	20	10	-	-	-	-	20
2-Butanol	-	20	-	-	10	-	-	-	-	-	-	-
Ethylene Glycol	-	-	-	-	-	-	-	-	-	10	-	-
Propylene Glycol	-	-	-	-	-	-	-	-	5	-	-	-
Water	10	20	10	10	10	20	10	10	10	10	10	10
Total(%)	100	100	100	100	100	100	100	100	100	100	100	100

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TABLE 3 (Dose Ratio ppm For Various Examples):

	#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12
Hydrocarbon fuel	Gas	#2D	Gas	#2D	Gas	Gas	Gas	Gas	#2D	Gas	#2D	Gas
Dose Ratio	2K	4K	2K	2K	2K	4K	2K	2K	2K	2K	2K	2K
Kerosene	0	0	0	0	0	0	100	150	0	100	100	0
Surfactant(s)	350	150	400	400	350	150	300	300	400	300	350	350
Co-surfactant(s)	100	50	50	50	100	50	50	0	50	50	0	100
Water	50	50	50	50	50	50	50	50	50	50	50	50
Total ppm in fuel	500	250	500	500	500	250	500	500	500	500	500	500
Treatment cost/gal	55	17	51	95	99	25	89	52	88	42	56	100

Note:

a. Dose ratio 2K = 2,000:1, and 4K = 4,000:1. Dose ratio used was based on the relative emulsifying ability of each particular additive surfactant/co-surfactant combination. Some additives were much stronger than others, and could be used at a lower dose rate.

b. Treatment costs/gallon are all relative, based on example #12 (the most expensive) being given the arbitrary value of 100.

Example #1

Additive #1

Concentrated micro-emulsion additive #1 was prepared by mixing the following ingredients:

Liquid	Proportion	Ratio	PPM at 2,000:1
Ninate 411	70.0%	7.0	350
Isopropyl Alcohol	20.0%	2.0	100
Water	10.0%	1.0	50
	100.0%		500

Test #1a

Concentrated micro-emulsion additive #1 was mixed with 92 octane unleaded gasoline using a treat rate of 500 ppm (2,000:1), or about 50 ppm of additional water. This fuel was then used in a 1990 Lexus 400 (odometer reading about 250,000 miles) for 2 weeks using a typical daily commuter driving pattern.

Concentrated micro-emulsion additive #1 was then mixed with 89 octane unleaded gasoline using a treat rate of 500 ppm (2,000:1), or about 50 ppm of additional water.

The same Lexus 400 vehicle (which normally requires the use of untreated 92 octane fuel) could then use this emulsified 89 octane fuel without any noticeable engine power loss, knocking or pinging, or driveability problems. Testing protocol was generally the CRC E-15-92 vehicle octane number requirement rating.

Test #1b

Mileage testing on this same vehicle showed about a 10% improvement using the 89 octane emulsified fuel over the 92 octane untreated fuel (from 19.0 mpg up to 20.9 mpg).

Test #1c

Exhaust emissions were also compared for this vehicle using the California Smog Check protocol (average of 6 tests). Comparison was between untreated 92 octane fuel, and emulsified 89 octane fuel (after the 2 week period described above). Average hydrocarbon (HC) emissions reduced from 20 ppm, down to 16 ppm (a 20% reduction). Carbon monoxide (CO) emissions remained unchanged at 0.00% for both fuels (i.e. below the detection level of the test equipment).

Example #2

Additive #2

Concentrated micro-emulsion additive #2 was prepared by mixing the following ingredients:

Liquid	Proportion	Ratio	PPM at 4,000:1
Aristonate "M"	35.0%	3.0	150
Aristonate "L"	25.0%		
2-butanol	20.0%	1.0	50
Water	20.0%	1.0	50

	100.0%		250

Test #2a

Concentrated micro-emulsion additive #2 was mixed with California Reformulated #2 automotive diesel fuel using a treat rate of 250 ppm (4,000:1), or about 50 ppm of additional water.

This fuel was used in a 1972 Mercedes Benz 220D/8 automobile fitted with a 4 cylinder diesel engine (2.2 liter, indirect injection, naturally aspirated). Odometer reading was about 207,000 miles

The exhaust smoke level was measured by the "snap-idle" test using a N.T.K. model ST-100 diesel emission smoke tester (manufactured by Komyo Rikagku Kogyo K.K. of Japan).

After 2 weeks of typical commuter driving, the exhaust smoke levels were reduced about 15% (average of 6 tests) from using the emulsified fuel over the untreated fuel (opacity from 14.8% down to 12.6%).

Test #2b

Mileage testing on this same vehicle showed about a 6% improvement using the emulsified fuel over the untreated fuel (from 34.0 mpg to 36.0 mpg).

Test #2c

The exhaust NO_x level was measured at idle using a "Nonoxor" NOx analyzer (manufactured by Bacharach Inc., their model #19-7036).

NO_x levels reduced about 5% (average of 6 tests) using the emulsified fuel over the untreated fuel (NO_x levels from 75 ppm down to 71 ppm).

Example #3

Additive #3

Concentrated micro-emulsion additive #3 was prepared by mixing the following ingredients:

Liquid	Proportion	Ratio	PPM at 2,000:1
Surfonic L24-9	40.0%		
Surfonic L24-4	40.0%	8.0	400

Methanol	10.0%	1.0	50
Water	10.0%	1.0	50
	100.0%		500

Test #3a

Concentrated micro-emulsion additive #3 was mixed with 92 octane unleaded gasoline using a treat rate of 500 ppm (2,000:1), or about 50 ppm of additional water. This fuel was then used in a 1990 Lexus 400 (odometer reading about 250,000 miles) for 2 weeks using a typical daily commuter driving pattern.

Concentrated micro-emulsion additive #3 was then mixed with 87 octane unleaded gasoline using a treat rate of 500 ppm (2,000:1), or about 50 ppm of additional water.

The same Lexus 400 vehicle (which normally requires the use of untreated 92 octane fuel) could then use this emulsified 87 octane fuel without any noticeable engine power loss, knocking or pinging, or driveability problems. Testing protocol was generally the CRC E-15-92 vehicle octane number requirement rating.

Test #3b

Mileage testing on this same vehicle showed about a 10% improvement using the 87 octane emulsified fuel over the 92 octane untreated fuel (from 19.0 mpg up to 20.9 mpg).

Test #3c

Exhaust emissions were also compared for this vehicle using the California Smog Check protocol (average of 6 tests). Comparison was between untreated 92 octane fuel, and emulsified 87 octane fuel (after the 2 week period described above). Average hydrocarbon (HC) emissions reduced from 20 ppm down to 8 ppm (a 60% reduction). Carbon monoxide (CO) emissions remained unchanged at 0.00% for both fuels (i.e. below the detection level of the test equipment).

Example #4

Additive #4

Concentrated micro-emulsion additive #4 was prepared by mixing the following ingredients:

Liquid	Proportion	Ratio	PPM at 2,000:1

Span 80	55.0%		
Makon 8	25.0%	8.0	400
Ethanol	10.0%	1.0	50
Water	10.0%	1.0	50
	100.0%		500

Test #4a

Concentrated micro-emulsion additive #4 was mixed with California Reformulated #2 automotive diesel fuel using a treat rate of 500 ppm (2,000:1), or about 50 ppm of additional water.

This fuel was then used in a 1979 Peugeot 504 sedan fitted with a 43 cylinder diesel engine (2.3 liter, indirect injection). Odometer reading was about 117,000 miles.

The exhaust smoke level was measured by the "snap-idle" test using a N.T.K. model ST-100 diesel emission smoke tester (manufactured by Komyo Rikagaku Kogyo K.K. of Japan).

Smoke levels reduced about 6% (average of 6 tests) using the emulsified fuel over the untreated fuel (opacity from 35% down to 33%).

Test #4b

Mileage testing on this same vehicle showed a slight improvement using the emulsified fuel over the untreated fuel (from 37.0 mpg to 37.1 mpg).

Test #4c

The exhaust NO_x level was measured at idle using a "Nonoxor" NO_x analyzer (manufactured by Bacharach Inc., their model #19-7036).

NO_x levels reduced about 3% (average of 6 tests) using the emulsified fuel over the untreated fuel (NO_x levels from 65 ppm down to 63 ppm).

Example #5

Additive #5

Concentrated micro-emulsion additive #5 was prepared by mixing the following ingredients:

Liquid	Proportion	Ratio	PPM at 2,000:1

Sodium Cocyl Sarcosinate	.3%	7.0	350
Span 80	65.7%		
Ethyl Alcohol	10.0%		
2-butanol	10.0%	1.0	100
Water	10.0%	1.0	50
	100.0%		500

Note: We actually used 14.3% Hamposyl C-30 in our additive #5. Hamposyl C-30 is 30% Sodium Cocyl Sarcosinate and 70% water. So 14.3% C-30 = 4.3% Sodium Cocyl Sarcosinate + 10.0% water. i.e. we did not need to add any extra water.

Test #5a

Concentrated micro-emulsion additive #5 was mixed with 87 octane unleaded gasoline using a treat rate of 500 ppm (2,000:1), or about 50 ppm of additional water.

This fuel was then used in a 1992 Honda Accord 4 door sedan fitted with the 2.1 liter 4 cylinder, 16 valve, fuel injected gasoline engine. The odometer reading was about 93,000 miles.

After two weeks of typical commuter driving, the exhaust emissions were then compared for this vehicle using the California Smog Check protocol (average of 6 tests). Comparison was between untreated 87 octane fuel, and emulsified 87 octane fuel.

Average hydrocarbon (HC) emissions reduced from 16 ppm down to 15 ppm (about a 6%

(CO) emissions remained unchanged at 0.00% for both fuels (i.e.

Additive #6

Concentrated micro-emulsion additive #6 was prepared by mixing the following

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Ninate 411	30.0%		
Makon 4	20.0%	3.0	150
Makon 8	10.0%		
Isopropyl Alcohol	20.0%	1.0	50
Water	20.0%	1.0	50
	100.0%		250

Test #6a

Concentrated micro-emulsion additive #6 was mixed with 92 octane unleaded gasoline using a treat rate of 250 ppm (4,000:1), or about 50 ppm of additional water. This fuel was then used in a 1990 Lexus 400 (odometer reading about 250,000 miles) for 2 weeks using a typical daily commuter driving pattern.

Concentrated micro-emulsion additive #6 was then mixed with 87 octane unleaded gasoline using a treat rate of 250 ppm (4,000:1), or about 50 ppm of additional water.

The same Lexus 400 vehicle (which normally requires the use of untreated 92 octane fuel) could then use this emulsified 87 octane fuel without any noticeable engine power loss, knocking or pinging, or driveability problems. Testing protocol was generally the CRC E-15-92 vehicle octane number requirement rating.

Test #6b

Mileage testing on this same vehicle showed about a 10% improvement using the 87 octane emulsified fuel over the 92 octane untreated fuel (from 19.0 mpg up to 20.9 mpg).

Test #6c

Exhaust emissions were also compared for this vehicle using the California Smog protocol (average of 6 tests). Comparison was between untreated 92 octane fuel, and emulsified 87 octane fuel (after the 2 week period described above). Average hydrocarbon (HC) emissions reduced

20 ppm down to 10 ppm (a 50% reduction). Carbon monoxide (CO) emissions remained unchanged at 0.00% for both fuels (i.e. below the detection level of the test equipment).

Example #7

Additive #7

Concentrated micro-emulsion additive #7 was prepared by mixing the following ingredients:

Liquid	Proportion	Ratio	PPM at 2,000:1
Kerosene	20.0%		100
TEA Lauryl Sulfate	6.7%		
Span 80	53.3%	6.0	300
Isopropyl Alcohol	10.0%	1.0	50
Water	10.0%	1.0	50
	100.0%		500

Note: We actually used 16.6% Norfox TLS in our additive #7. Norfox TLS is 40% TEA Lauryl Sulfate and 60% water. So 16.7% represents 6.67% TEA Lauryl Sulfate and 10.0% water. i.e. we did not need to add any extra water.

Test #7a

Concentrated micro-emulsion additive #7 was mixed with 87 octane unleaded gasoline using a treat rate of 500 ppm (2,000:1), or about 50 ppm of additional water.

This fuel was then used in a 1996 Dodge RAM 1500 pick-up truck (fitted with the 5.2 liter V8 "magnum" gasoline engine), the odometer reading was about 16,500 miles.

The very next day, exhaust emissions were then compared for this vehicle using the California Smog Check protocol (average of 6 tests). Comparison was between untreated 87 octane fuel, and emulsified 87 octane fuel.

Average hydrocarbon (HC) emissions reduced from 20 ppm down to 2 ppm (a 90% reduction). Carbon monoxide (CO) emissions remained unchanged at 0.00% for both fuels (i.e. below the detection level of the test equipment).

Test #7b

Mileage testing on this same vehicle showed about a 2.2% improvement using the 87 octane emulsified fuel over the 87 octane untreated fuel (from 18.1 mpg up to 18.5 average).

Example #8

Additive #8

Concentrated micro-emulsion additive #8 was prepared by mixing the following ingredients:

Liquid	Proportion	Ratio	PPM at 2,000:1
Kerosene	30.0%		150
Ninate 411	30.0%		
Makon 4	20.0%	6.0	300
Makon 8	10.0%		
Water	10.0%	1.0	50
	100.0%		500

Test #8a

Concentrated micro-emulsion additive #8 was mixed with 92 octane unleaded gasoline using a treat rate of 500 ppm (2,000:1), or about 50 ppm of additional water. This fuel was then used in a 1990 Lexus 400 (odometer reading about 250,000 miles) for 2 weeks using a typical daily commuter driving pattern.

Concentrated micro-emulsion additive #8 was then mixed with 89 octane unleaded gasoline using a treat rate of 500 ppm (2,000:1), or about 50 ppm of additional water.

The same Lexus 400 vehicle (which normally requires the use of untreated 92 octane fuel) could then use this emulsified 89 octane fuel without any noticeable engine power loss, knocking or pinging, or driveability problems. Testing protocol was generally the CRC E-15-92 vehicle octane number requirement rating.

Test #8b

Mileage testing on this same vehicle showed about a 5.0% improvement using the 89 octane emulsified fuel over the 92 octane untreated fuel (from 19.0 mpg up to 20.0 mpg).

Test #8c

Exhaust emissions were also compared for this vehicle using the California Smog Check protocol (average of 6 tests). Comparison was between untreated 92 octane fuel, and emulsified 89 octane fuel (after the 2 week period described above). Average hydrocarbon (HC) emissions

reduced from 20 ppm down to 11 ppm (a 45% reduction). Carbon monoxide (CO) emissions remained unchanged at 0.00% for both fuels (i.e. below the detection level of the test equipment).

Example #9

Additive #9

Concentrated micro-emulsion additive #9 was prepared by mixing the following ingredients:

Liquid	Proportion	Ratio	PPM at 2,000:1
Span 80	50.0%		
Ninate 411	30.0%	8.0	400
Methanol	5.0%		
Propylene Glycol	5.0%	1.0	50
Water	10.0%	1.0	50
	100.0%		500

Test #9a

Concentrated micro-emulsion additive #9 was mixed with California Reformulated #2 automotive diesel fuel using a treat rate of 500 ppm (2,000:1), or about 50 ppm of additional water.

This fuel was then used in a 1992 Dodge D250 pick up truck fitted with a Cummins 6 cylinder diesel engine (5.9 liter, direct injection, turbocharged and intercooled). Odometer reading was about 153,000 miles.

The exhaust smoke level was measured by the "snap-idle" test using a N.T.K. model ST-100 diesel emission smoke tester (manufactured by Komyo Rikagaku Kogyo K.K. of Japan).

Smoke levels reduced about 23% (average of 6 tests) using the emulsified fuel over the untreated fuel (opacity from 14.8% down to 11.3%).

Test #9b

Mileage testing on this same vehicle showed about a 1.5% improvement using the emulsified fuel over the untreated fuel (from 21.3 mpg up to 21.6 mpg).

Test #9c

The exhaust NO_x level was measured at idle using a "Nonoxor" NOx analyzer (manufactured by Bacharach Inc., their model #19-7036).

NO_x levels reduced about 6% (average of 6 tests) using the emulsified fuel over the untreated fuel (NO_x levels from 165 ppm down to 154 ppm).

Example #10

Additive #10

Concentrated micro-emulsion additive #10 was prepared by mixing the following ingredients:

Liquid	Proportion	Ratio	PPM at 2,000:1
Kerosene	20.0%		100
Surfonic N-40	30.0%		
Surfonic N-95	30.0%	6.0	300
Ethylene Glycol	10.0%	1.0	50
Water	10.0%	1.0	50
	100.0%		500

Test #10a

Concentrated micro-emulsion additive #10 was mixed with 92 octane unleaded gasoline using a treat rate of 500 ppm (2,000:1), or about 50 ppm of additional water. This fuel was then used in a 1990 Lexus 400 (odometer reading about 250,000 miles) for 2 weeks using a typical daily commuter driving pattern.

Concentrated micro-emulsion additive #10 was then mixed with 87 octane unleaded gasoline using a treat rate of 500 ppm (2,000:1), or about 50 ppm of additional water.

The same Lexus 400 vehicle (which normally requires the use of untreated 92 octane fuel) could then use this emulsified 87 octane fuel without any noticeable engine power loss, knocking or pinging, or driveability problems. Testing protocol was generally the CRC E-15-92 vehicle octane number requirement rating.

Test #10b

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Mileage testing on this same vehicle showed about a 10% improvement using the 87 octane emulsified fuel over the 92 octane untreated fuel (from 19.0 mpg up to 20.0 mpg).

Test #10c

Exhaust emissions were also compared for this vehicle using the California Smog Check protocol (average of 6 tests). Comparison was between untreated 92 octane fuel, and emulsified 87 octane fuel (after the 2 week period described above). Average hydrocarbon (HC) emissions reduced from 20 ppm down to 12 ppm (a 40% reduction). Carbon monoxide (CO) emissions remained unchanged at 0.00% for both fuels (i.e. below the detection level of the test equipment).

Example #11

Additive #11

Concentrated micro-emulsion additive #11 was prepared by mixing the following ingredients:

Liquid	Proportion	Ratio	PPM at 2,000:1
Kerosene	20.0%		100
CocoAmidoSultaine	10.0%		
Ninate 411	60.0%	7.0	350
Water	10.0%	1.0	50
	100.0%		500

Note: We actually used 20.0% Chembetaine CAS in our additive #11. Chembetaine CAS is 50% Cocoamidopropyl Hydroxyl Sultaine and 50% water. So 20.0% represents 10% Cocoamidopropyl Hydroxyl Sultaine and 10.0% water, i.e. we did not need to add any extra water.

Test 11a

Concentrated micro-emulsion additive #11 was mixed with California Reformulated #2 automotive diesel fuel using a treat rate of 500 ppm (2,000:1), or about 50 ppm of additional water.

This fuel was then used in a 1982 Mercedes Benz 300SD automobile fitted with a 5 cylinder diesel engine (3.0 liter, indirect injection, turbocharged). The odometer reading was about 240,000 miles.

The exhaust smoke level was measured by the "snap idle" test using a N.T.K. model ST-100 diesel emission smoke tester (manufactured by Komyo Rigagku Kogyo K.K. of Japan).

After 2 weeks of typical commuter driving, the exhaust smoke levels were reduced about 18% (average of 6 tests) from using the emulsified fuel over the untreated fuel (opacity reduction from 18.8% down to 15.5%)

Test 11b

Mileage testing on this same vehicle showed about a 6% improvement using the emulsified fuel over the untreated fuel (from 24.1 mpg up to 25.5 average).

Test 11c

The exhaust NO_x level was measured at idle using a "Nonoxor" NOx analyzer (manufactured by Bacharach Inc., their model #19-7036). NO_x levels reduced about 5% (average of 6 tests) using the emulsified fuel over the untreated fuel (NO_x levels down from 75 ppm down to 71 ppm).

Example #12

Additive #12

Concentrated micro-emulsion additive #12 was prepared by mixing the following ingredients:

Liquid	Proportion	Ratio	PPM at 2,000:1
Arquat T-50	20.0%		
Span 80	50.0%	7.0	350
Isopropyl Alcohol	20.0%	2.0	100
Water	10.0%	1.0	50
	100.0%		500

Note: We actually used 40.0% Arquat T-50 in our additive #12. Arquat T-50 is 50% Trimethyl Tallowalkyl Quaternary Ammonium Chloride and 50% isopropyl alcohol (IPA). So this

40.0% represents 20% Trimethyl Tallowalkyl Quat and 20.0% isopropyl alcohol. i.e. we did not need to add any extra IPA to act as the co-surfactant.

Test #12a

Concentrated micro-emulsion additive #12 was mixed with 87 octane unleaded California reformulated gasoline using a treat rate of 500 ppm (2,000:1), or about 50 ppm of additional water.

This fuel was then used in a 1992 Honda Accord 4 door sedan fitted with the 2.1 liter, 4 cylinder, 16 valve, fuel injected gasoline engine. The odometer reading was about 108,000 miles.

After 2 weeks of typical commuter driving, the exhaust emissions were then compared for this vehicle using the California Smog Check protocol (average of 6 tests). Comparison was between untreated 87 octane fuel, and emulsified 87 octane fuel.

Average hydrocarbon (HC) emissions reduced from 16 ppm down to 8 ppm (about a 50% reduction). Carbon monoxide (CO) emissions remained unchanged at 0.00% for both fuels (i.e. below the detection level of the test equipment).

Test #12b

Mileage testing on this same vehicle showed about a 10% improvement using the 87 octane emulsified fuel over the 87 octane untreated fuel (from 32.9 mpg up to 36.2 mpg average).

Comments on Test Results (Examples #1 through #12)

Examples #1 through #12 show that it is possible to employ significantly different types of surfactants and co-surfactants and still achieve a reasonable result, even with a very low water content (typically only 50 ppm additional water in the fuel).

Example #1 uses only one surfactant.

Examples #2 through #12 use mixtures of surfactants.

Examples #1 and #2 use ionic surfactants only.

Examples #3, 4, and 10 use non-ionic surfactants only.

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Examples #5 through #9 use mixtures of ionic and non-ionic surfactants.

Example #11 uses a mixture of amphoteric and anionic surfactants.

Example #12 uses a mixture of cationic and non-ionic surfactants.

Examples #8 and #11 use no co-surfactants.

Examples #1, 2, 3, 4, 6, 7, 10 and #12 use only one co-surfactant.

Examples #5 and #9 use a mixture of co-surfactants.

Examples #1,2,3,4,5,6,7 and #12 use different alcohols as co-surfactants.

Examples #9 and #10 use different glycols as co-surfactants.

Example #9 uses a mixture of alcohol and glycol co-surfactants.

Examples #2, 4 ,9 and #11 use diesel as the hydrocarbon fuel.

Examples #1, 3, 5, 6, 7, 8,10 and #12 use gasoline as the hydrocarbon fuel.

It is obvious from the test results that some additives are much better than others in the critical ratio of performance to cost per gallon treated. It is this ratio that determines to a large extent the commercial acceptability of any given additive. For this reason. we have not included any examples having a "large" water content (over 200 ppm). These additives would have required proportionally greater quantities of surfactants, and would therefore have been prohibitively expensive to use. If we double the water content, we would also have to almost double the surfactant content, and hence almost double the price. The question would then be, do we get double the performance for double the price? Comparison between examples #6 and #8 clearly show that this would not be the case.

Comparing examples #1 through #12, clearly #2 would be the "best" diesel fuel additive and #6 would be the "best" gasoline additive based simply on the cost/benefit ratio.

However, there appears to be no great difference between most of the surfactant mixtures used in examples #1 through #12. When deciding whether one additive would be better than

another, other factors may have to be considered. For example, additive #2 would be illegal in the USA because one of the surfactants used contains the metal sodium.

With regard to the best co-surfactant to use, we have found that butyl alcohol usually gives the strongest emulsions because of its solubility compromise between water and hydrocarbon. However, other factors such as flash point and freeze suppression must also be considered. For fuels subject to extremely low ambient temperatures, we generally prefer ethylene glycol as the co-surfactant (freezing points below - 40 deg C can be produced).

In order to maximize the cost/benefit ratio of our additives, we have tried where possible to select surfactants which not only make a more stable emulsion but also perform additional functions such as lubrication, corrosion resistance and biocide action (important in an emulsion).

Generally, a minimum number of at least two surfactants would be required (each one acting against the other in order to achieve exactly the right HLB balance for the specific fuel being emulsified), in this way the minimum quantity of surfactant necessary to achieve long term fuel stability could be realized. For a good technical explanation of this phenomena please refer to McCoy (US# 3,876,391).

Gasoline emulsions usually require a slightly different HLB balance than diesel emulsions. However, it is possible to formulate an additive with an excess of surfactants such that adequate results could be obtained irrespective of the hydrocarbon fuel being treated (i.e. the same additive could be used in both gasoline and diesel fuel). Even fuels within a specific group will still vary slightly with regard to their required HLB balance. Some diesel fuels requiring more or slightly different surfactants than others. For this reason we prefer to have a larger quantity of surfactant than is strictly necessary to be sure of obtaining long term fuel stability.

In examples #1 through #12 we have used only one or two surfactants to produce the additives and consequently formed relatively "crude" additives. Those skilled in the art of surfactant chemistry would easily be able to improve on the effectiveness of the surfactant(s) and co-surfactant(s) chemical package and hence produce more "sophisticated" additives. This would

allow for the use of less surfactants per unit of water emulsified, and hence significantly improve cost effectiveness.

Examples #1 through #12 require a "crude" surfactant to water ratios typically 6:1 in order to produce sufficiently stable fuel emulsions. However, when using "sophisticated" surfactant packages, typical ratios would be 3:1 or less (sometimes much less).

Examples #13 through #20 which follow are used to demonstrate how the use of more "sophisticated" chemical packages can significantly reduce the quantities of surfactants required, and thereby improve the cost effectiveness of the additive.

TABLE 4 (Percentage Composition For Examples #13 through #20):

	#13	#14	#15	#16	#17	#18	#19	#20
Kerosene	-	-	-	16.7	-	-	-	-
Amine alkylbenzene sulphonate	21.3	21.3	21.3	26.7	21.2	21.4	27.4	22.2
POE (20) sorbitan monoleate	10.4	10.4	10.4	3.3	7.7	12.9	16.5	2.2
Tall oil fatty acids	9.2	9.2	9.2	6.6	15.3	5.3	6.8	-
Oleyl imidazoline hydrochloride	4.8	4.8	4.8	-	-	6.4	8.2	-
Oleamide diethanolamine	8.0	8.0	8.0	13.3	7.7	10.7	13.6	4.5
Methanol	18.0	18.0	18.0	-	-	16.1	20.6	-
Iso propanol	-	-	-	16.7	14.3	-	-	-
N-butanol	-	-	-	-	-	-	-	11.6
Ethylene glycol n-butyl ether	3.2	3.2	3.2	-	-	4.3	5.5	-
Dipropylene glycol methyl ether	0.7	0.7	0.7	-	-	1.1	1.4	2.3
Water	24.4	24.4	24.4	16.7	33.8	21.8	00.0	57.2
Total(%)	100	100	100	100	100	100	100	100

TABLE 5 (Dose Ratio ppm For Various Examples):

	#13	#14	#15	#16	#17	#18	#19	#20
Hydrocarbon fuel	Gas	Gas	Gas	Gas	Gas	#2D	#2D	Gas
Dose Ratio	7.5K	12K	50K	4K	4K	10K	10K	6K
Kerosene	0	0	0	42	0	0	0	0

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Surfactant(s)	72	45	11	124	130	57	72	48
Co-surfactant(s)	29	18	4	42	35	21	28	23
Water	32	20	5	42	85	22	0	95
Total ppm in fuel	133	83	20	250	250	100	100	166
Treatment cost/gal	11	7	2	23	18	9	11	7

Note:

a. Dose ratio 4K = 4,000:1, and 7.5K = 7,500:1. Dose ratio used was based on the relative emulsifying ability of each particular additive surfactant/co-surfactant combination. Some additives were much stronger than others, and could be used at a lower dose rate.

b. Treatment costs/gallon are all relative and for comparison only, based on example #12 (the most expensive of all our examples) being given the arbitrary value of 100.

TABLE 6 (Performance Analysis Tests #1 through #20)

Test #	(%) Cost	(ppm) Water	Emissions Reduction (%) MPG	(%) HC	(%) CO	(%) NOX	(%) PM
1	55	50	10	20	--	--	--
2	17	50	6	--	--	5	15
3	51	50	10	60	--	--	--
4	95	50	--	--	--	3	6
5	99	50	4	6	--	--	--
6	25	50	10	50	--	--	--
7	89	50	2	90	--	--	--
8	52	50	5	45	--	--	--
9	88	50	2	--	--	6	23
10	42	50	10	40	--	--	--
11	56	50	6	--	--	5	18
12	100	50	10	50	--	--	--
13	11	32	--	13	10	36	--

14	7	20	10	80	--	--	--
15	2	5	2.5	50	--	--	--
16	23	42	12	52	85	1	--
17	18	85	--	98	+35	95	--
18	9	22	14	49	--	9	22
19	11	0	--	--	--	5	15
20	7	95	10	90	--	--	--

Example #13

Additive #13

Concentrated micro-emulsion additive #13 was prepared by mixing the following ingredients:

Liquid	Proportion (%)	Ratio	PPM at 7,500:1
Amine alkylbenzene sulphonate	21.3		
POE (20) sorbitan monooleate	10.4	2.25	72
Tall oil fatty acids	9.2		
Oleyl imidazoline hydrochloride	4.8		
Oleamide diethanolamine	8.0		
Methanol	18.0	0.9	29
Ethylene glycol n-butyl ether	3.2		
Dipropylene glycol methyl ether	0.7		
Water	24.4	1.0	32
	100.0%		133

Test #13

Concentrated micro-emulsion additive #13 was mixed with 87 octane unleaded gasoline using a treat rate of 133 ppm (7,500:1), or about 32 ppm of additional water. This fuel was then used in a 1993 Dodge Shadow automobile. This vehicle was then tested using Federal Test Procedure (FTP) described in 40 CFR § 600, appendix 1.

The following results indicate exhaust emissions reductions for both city and highway driving:-

Emission Gas	City Driving	Highway Driving
HC (hydrocarbons)	-7.3%	-18.8%
CO (carbon monoxide)	-5.0%	-14.7%
NOx (nitrogen oxides)	-11.8%	-29.9%

Example #14

Additive #14

Concentrated micro-emulsion additive #14 was prepared by mixing the following ingredients:

Liquid	Proportion (%)	Ratio	PPM at 12,000:1
Amine alkylbenzene sulphonate	21.3		
POE (20) sorbitan monooleate	10.4	2.25	45
Tall oil fatty acids	9.2		
Oleyl imidazoline hydrochloride	4.8		
Oleamide diethanolamine	8.0		
Methanol	18.0	0.9	18
Ethylene glycol n-butyl ether	3.2		
Dipropylene glycol methyl ether	0.7		
Water	24.4	1.0	20
	100.0%		83

Test #14a

Concentrated micro-emulsion additive #14 was mixed with 92 octane unleaded gasoline using a treat rate of 83 ppm (12,000:1), or about 20 ppm of additional water. This fuel was then used in a 1990 Lexus 400 (odometer reading about 250,000 miles) for 2 weeks using a typical daily commuter driving pattern.

Concentrated micro-emulsion additive #14 was then mixed with 89 octane unleaded gasoline using a treat rate of 83 ppm (12,000:1), or about 20 ppm of additional water.

The same Lexus 400 vehicle (which normally requires the use of untreated 92 octane fuel) could then use this emulsified 89 octane fuel without any noticeable engine power loss, knocking, pinging, or driveability problems. Testing protocol was generally the CRC E-15-92 vehicle octane number requirement rating.

Test #14b

Mileage testing on this same vehicle showed about a 10% improvement using the 89 octane emulsified fuel over the 92 octane untreated fuel (from 19.0 mpg up to 20.9 mpg).

Test #14c

Exhaust emissions were also compared for this vehicle using the California Smog protocol (average of 6 tests). Comparison was between untreated 92 octane fuel, and emulsified 89 octane fuel (after the 2 week period described above). Average hydrocarbon (HC) emissions reduced 20 ppm down to 4 ppm (a 80% reduction). Carbon monoxide (CO) emissions remained unchanged at 0.00% for both fuels (i.e. below the detection level of the test equipment).

Example #15

Additive #15

Concentrated micro-emulsion additive #15 was prepared by mixing the following ingredients:

Liquid	Proportion (%)	Ratio	PPM at 50,000:1
Amine alkylbenzene sulphonate	21.3		
POE (20) sorbitan monooleate	10.4	2.25	11
Tall oil fatty acids	9.2		
Oleyl imidazoline hydrochloride	4.8		
Oleamide diethanolamine	8.0		
Methanol	18.0	0.9	4
Ethylene glycol n-butyl ether	3.2		
Dipropylene glycol methyl ether	0.7		
Water	24.4	1.0	5
	100.0%		20

Test #15a

Having just completed test #14, the fuel remaining in the fuel tank of the Lexus 400 test vehicle was estimated to be about 4 gallons (test fuel #14 having 20 ppm of additional water). Exactly 12 gallons of untreated 89 octane gasoline was then added to this fuel tank. In this way, test fuel #14 was diluted to make test fuel #15 (which should then contain about 5 ppm of additional water). Equivalent dose ratio of 50,000:1 was estimated for this fuel (as shown above).

The same Lexus 400 vehicle (which normally requires the use of untreated 92 octane fuel) could then use this diluted emulsified 89 octane fuel without any noticeable engine power loss, knocking, pinging, or driveability problems. Testing protocol was generally the CRC E-15-92 vehicle octane number requirement rating.

Test #15b

Mileage testing on this same vehicle still showed about a 2.5% improvement using the 89 octane emulsified fuel over the 92 octane untreated fuel (from 19.0 mpg up to 19.5 mpg).

Test #15c

Exhaust emissions were also compared for this vehicle using the California Smog protocol (average of 6 tests). Comparison was between untreated 92 octane fuel, and diluted emulsified 89 octane fuel. Average hydrocarbon (HC) emissions reduced 20 ppm down to 10 ppm (a 50% reduction). Carbon monoxide (CO) emissions remained unchanged at 0.00% for both fuels (i.e. below the detection level of the test equipment).

Example #16

Additive #16

Concentrated micro-emulsion additive #16 was prepared by mixing the following ingredients:

Liquid	Proportion (%)	Ratio	PPM at 4,000:1
Kerosene	16.7	----	42
Amine alkylbenzene sulphonate	26.7		
POE (20) sorbitan monooleate	3.3	2.95	124

Tall oil fatty acids	6.6		
Oleamide diethanolamine	13.3		
Iso-propanol	16.7	1.0	42
Water	16.7	1.0	42
	100.0%		250

Test #16

Concentrated micro-emulsion additive #16 was mixed with 85 octane unleaded gasoline using a treat rate of 250 ppm (4,000:1), or about 42 ppm of additional water. This fuel was then used in a 1995 Toyota Corolla automobile. This vehicle was then tested for exhaust emission reductions using the EPA "IM240" test protocol at one of the State of Colorado official smog check stations.

The following results indicate exhaust emissions reductions:-

Emission Gas	Reduction
HC (hydrocarbons)	- 52%
CO (carbon monoxide)	- 85%
NOx (nitrogen oxides)	- 1%
CO2 (carbon dioxide)	- 12%

Example #17

Additive #17

Concentrated micro-emulsion additive #17 was prepared by mixing the following ingredients:

Liquid	Proportion (%)	Ratio	PPM at 4,000:1
Amine alkylbenzene sulphonate	21.2		
POE (20) sorbitan monooleate	7.7	1.53	130
Tall oil fatty acids	15.3		
Oleamide diethanolamine	7.7		
Iso-propanol	14.3	0.4	35
Water	33.8	1.0	85

	100.0%	250

Test #17

Concentrated micro-emulsion additive #17 was mixed with 85 octane unleaded gasoline using a treat rate of 250 ppm (4,000:1), or about 85 ppm of additional water. This fuel was then used in a 1995 Ford Taurus automobile. This vehicle was then tested for exhaust emission reductions using the EPA "IM240" test protocol at one of the State of Colorado official smog check stations.

The following results indicate exhaust emissions reductions:-

Emission Gas	Reduction
HC (hydrocarbons)	- 98%
CO (carbon monoxide)	+ 35%
NOx (nitrogen oxides)	- 95%
CO2 (carbon dioxide)	no change

Example #18

Additive #18

Concentrated micro-emulsion additive #18 was prepared by mixing the following ingredients:

Liquid	Proportion (%)	Ratio	PPM at 10,000:1
Amine alkylbenzene sulphonate	21.4		
POE (20) sorbitan monooleate	12.9	2.59	57
Tall oil fatty acids	5.3		
Oleyl imidazoline hydrochloride	6.4		
Oleamide diethanolamine	10.7		
Methanol	16.1	0.95	21
Ethylene glycol n-butyl ether	4.3		
Dipropylene glygol methyl ether	1.1		
Water	21.8	1.0	22
	100.0%		100

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Test #18

Concentrated micro-emulsion additive #18 was mixed with the Chinese equivalent of US #2 diesel fuel using a treat rate of 100 ppm (10,000:1), or about 22 ppm of additional water. This fuel was then used in a 2½ ton Tong Fung truck. This vehicle was then tested by the official Chinese EPA for exhaust emission reductions using their "GB3842-3847-83" test protocol.

The following results indicate exhaust emissions reductions:-

Emission Gas	Reduction
HC (hydrocarbons)	+ 49%
CO (carbon monoxide)	no change
NOx (nitrogen oxides)	- 9%
CO2 (carbon dioxide)	- 14%
Exhaust smoke	- 22%

Concerning the higher than baseline HC emissions shown above, these are almost certainly caused by combustion chamber cleaning action of the fuel emulsion. If the truck would have been allowed to accumulate some highway/city mileage then this would have given time for the combustion chambers to be cleaned, and lower than baseline HC emissions realized.

Example #19

Additive #19

Concentrated micro-emulsion additive #19 was prepared by mixing the following ingredients:

Liquid	Proportion (%)	Ratio	PPM at 10,000:1
Amine alkylbenzene sulphonate	27.4		
POE (20) sorbitan monooleate	16.5	----	72
Tall oil fatty acids	6.8		
Oleyl imidazoline hydrochloride	8.2		
Oleamide diethanolamine	13.6		
Methanol	20.6	----	28
Ethylene glycol n-butyl ether	5.5		

Dipropylene glygol methyl ether	1.4		
Water	0.0	1.0	0.0
	100.0%		100

Test #19a

Concentrated micro-emulsion additive #19 was mixed with California reformulated #2 automotive diesel fuel using a treat rate of 166 ppm (6,000:1). This fuel was then used in a 1982 Mercedes Benz 300SD automobile fitted with an in-line 5 cylinder, 3.0 liter, indirect injection, turbocharged diesel engine (odometer reading about 240,000 miles).

This fuel, when first mixed, would not be a true emulsion (since there was no water phase in additive #19). Initial driver response reported no power, and exhaust smoke/NO_x was within baseline tolerance. However, by about ½ tank power started to build and by ¼ tank feeling was good, so smoke and NO_x levels were measured.

Exhaust smoke level was measured by the "snap idle" test using a N.T.K. model ST-100 diesel emission opacity/smoke tester (average of 6 readings). Exhaust smoke level had reduced 15% over baseline.

Test #19b

NO_x at idle was measured using a Nonoxor NOx analyzer manufactured by Bacharach Inc., their model #19-7036. NO_x levels were reduced about 5% over baseline.

Test #19c

Fuel economy for the first tank of fuel was within baseline tolerance. However, economy for the second tank improved significantly, showing a 5% increase. Third tank mileage was a strong 8% better than baseline.

Example #20

Additive #20

Concentrated micro-emulsion additive #20 was prepared by mixing the following ingredients:

Liquid	Proportion (%)	Ratio	PPM at 6,000:1
Amine alkylbenzene sulphonate	22.2		

POE (20) sorbitan monooleate	2.2	0.50	48
Oleamide diethanolamine	4.5		
N-butanol	11.6	0.24	23
Dipropylene glygol methyl ether	2.3		
Water	57.2	1.0	95
	100.0%		166

Test #20a

Concentrated micro-emulsion additive #20 was mixed with 92 octane unleaded gasoline using a treat rate of 166 ppm (6,000:1), or about 95 ppm of additional water. This fuel was then used in a 1990 Lexus 400 (odometer reading about 250,000 miles) for 2 weeks using a typical daily commuter driving pattern.

Concentrated micro-emulsion additive #20 was then mixed with 89 octane unleaded gasoline using a treat rate of 166 ppm (6,000:1), or about 95 ppm of additional water.

The same Lexus 400 vehicle (which normally requires the use of untreated 92 octane fuel) could then use this emulsified 89 octane fuel without any noticeable engine power loss, knocking, pinging, or driveability problems. Testing protocol was generally the CRC E-15-92 vehicle octane number requirement rating.

Test #20b

Mileage testing on this same vehicle showed about a 10% improvement using the 89 octane emulsified fuel over the 92 octane untreated fuel (from 19.0 mpg up to 20.9 mpg).

Test #20c

Exhaust emissions were also compared for this vehicle using the California Smog protocol (average of 6 tests). Comparison was between untreated 92 octane fuel, and emulsified 89 octane fuel (after the 2 week period described above). Average hydrocarbon (HC) emissions reduced 20 ppm down to 2 ppm (a 90% reduction). Carbon monoxide (CO) emissions remained unchanged at 0.00% for both fuels (i.e. below the detection level of the test equipment).